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EARTH RADIATION BUDGET EXPERIMENT (ERBE) DATA SETS FOR GLOBAL ENVIRONMENT AND CLIMATE CHANGE STUDIES

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1. INTRODUCTION

For a number of years there has been considerable interest in the earth's radiation budget (ERB) or energy balance, and entails making the best measurements possible of absorbed solar radiation, reflected shortwave radiation (RSW), thermal outgoing longwave radiation (OLR), and net radiation. ERB data are fundamental to the development of realistic climate models and studying natural and anthropogenic perturbations of the climate. Much of the interest and investigations in the earth's energy balance predated the age of earth-orbiting satellites (Hunt *et al*., 1986). Beginning in the mid 1960's earth-orbiting satellites began to play an important role in making measurements of the earth's radiation flux although much effort had gone into measuring ERB parameters prior to 1960 (House *et al*., 1986).

Beginning in 1974 and extending until the present time, three different satellite experiments (not all operating at the same time) have been making radiation budget measurements almost continually in time. Two of the experiments were totally dedicated to making radiation budget measurements of the earth (Smith *et al*., 1977; Jacobowitz *et al*., 1984; Barkstrom, 1984; Barkstrom and Smith, 1986), and the other experiment flown on NOAA sun-synchronous AVHRR weather satellites produced radiation budget parameters as a by-product (Gruber and Krueger, 1984; Ohring and Ellingson, 1984; Gruber, 1978). The heat budget data from the AVHRR satellites began collecting data in June 1974 and have operated almost continuously for 23 years producing valuable data for long term climate monitoring.

In 1975 a major advance in measuring the earth radiation budget was made with the earth radiation experiment (ERB) (Smith *et al*., 1977; Jacobowitz *et al*., 1984), the first satellite dedicated to measuring earth radiation budget. This experiment flew separate but nearly identical payloads at two different times on the *Nimbus-6* and *Nimbus-7* sun-synchronous satellites. The ERB instrument package on both of these satellites included two earth-viewing wide-field-of-view (WFOV) flat-plate radiometers: one that measured total irradiance (TOT) and the other that measured shortwave (SW) irradiance. The difference between the two is the outgoing longwave radiation (OLR). The WFOV radiometers viewed the earth's entire "disk" from *Nimbus-6* at the 1100-km altitude and from *Nimbus-7* at the 955-km altitude with equator-crossing times near 1200 and 2400 LST. The SW channel had a spectral range of 0.2 - 3.8 mm, and the TOT channel measured the irradiance from 0.2 to slightly greater than 50 mm. *Nimbus-6* collected usable data from July 1975 through June 1978. *Nimbus-7* collected data from November 1978 through 1990. *Nimbus-6* and *Nimbus-7* were equipped with scanners, but the scanner on *Nimbus-6* failed after one month and the *Nimbus-7* scanner failed after 19 months of operation.

In 1984 further advances were made with the Earth Radiation Budget Experiment (ERBE) (not to be confused with the earlier Nimbus ERB experiment) (Barkstrom, 1984; Barkstrom and Smith, 1986). This experiment consists of three satellites, two sun-synchronous National Oceanic and Atmospheric Administration (NOAA) polar orbiters, and one precessing orbiter, the earth radiation budget satellite (ERBS), that observes at varying local times. Measurements from these three satellites, independently and combined, provide the most accurate and best calibrated results thus far for observing the radiation budget of the earth. The ERBE instrument package on the satellites included earth-viewing narrow-field-of-view (NFOV) scanners as well as non-scanner WFOV active-cavity radiometers with different detectors and filters, but nearly the same viewing geometry as the WFOV flat-plate radiometers on the earlier Nimbus ERB experiment. The scanner instrument package contained three detectors to measure SW (0.2 - 5 µm), longwave (5 - 200 µm), and total waveband radiation (0.2 - 200 µm) (Kopia, 1986). Each detector scans the earth perpendicular to the satellite ground track from horizon-to-horizon. The nonscanner instrument package contained four earth-viewing channels and a solar channel (Luther, *et al*., 1986). For each channel there is a total spectral channel which is sensitive to all

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wavelengths and a shortwave channel which transmits only shortwave radiation from 0.2 - 5 mm. The major difference in the polar orbiters from the ERB experiment and ERBE is that the ERBE polar orbiters, *NOAA-9* and *NOAA-10* had different equator-crossing times (0230 and 0730 LST, respectively) and are in a lower orbit (870 km).

The ERBS was launched 5 October 1984, but the first archived data were from November 1984. The coarse spatial resolution WFOV on the ERBS continues to collect data although its high-spatial-resolution scanner failed 28 February 1990, after 64 months of successful operation. The *NOAA-9* satellite was launched 12 December 1984, and the first archived data were for February 1985. The *NOAA-9* scanner failed 20 January 1987, after two years of successful operation. The *NOAA-9* nonscanner failed 7 November 1988. The *NOAA-10* satellite was launched on 17 September 1986, and the first archived data were for November 1986. The *NOAA-10* scanner failed on 22 May 1989 after 31 months of successful operation. The *NOAA-10* nonscanner failed in 1992. With the combined ERBE and ERB experiment, there is a 20-year continuous time series of radiation flux data available for climate studies.

The purpose of this paper is to describe a subset of the 20-year ERB data set which will be made available over a web site located at NASA, Langley Research Center for secondary schools up through K-12. The data included at this web site is a 3-year subset of the ERBE scanner data set from ERBS, *NOAA-9*, and *NOAA-10* and does not include any of the other radiation flux data mentioned in this background material. More data will be added at a later date. The included references are a good source for becoming familiar with research about the radiation budget of the earth.

2. DATA DESCRIPTION

All data are monthly average gridded shortwave fluxes, longwave fluxes, and albedos from February 1985 through December 1987. This three year data set of albedos, longwave fluxes, and shortwave fluxes is from ERBE. ERBE (Barkstrom, 1984) is the first ERB instrument flown on multiple satellites to provide the necessary temporal sampling for studying the diurnal variations of regional broadband radiative parameters over the earth. Identical ERBE instruments were launched on the NASA Earth Radiation Budget Satellite (ERBS, 603 km altitude, 57 deg inclination) by the Space Shuttle Challenger in October 1984, and two National Oceanic and Atmospheric Administration (NOAA) sun-synchronous operational satellites: *NOAA-9* (852 km altitude, 14:30 equatorial crossing local time) launched in December 1984 and *NOAA-10* (833 km altitude, 07:30 equatorial crossing local time) in November 1986. The ERBE satellites have provided one of the most comprehensive and best resolved earth radiation budget measurements (ERB) measurements ever obtained.

This 3-year data set is taken from the ERBE S-4 product (S-4 Users Guide). The S-4 product contains the regional, zonal, and global time and space averages of all individual estimates of radiant exitance at top-of-atmosphere (TOA) for one month and one spacecraft or for a combination of data from different spacecraft. This data set only uses the S-4 scanner measurements for 2.5° x 2.5° monthly equal-angle regional averages. The first region of the grid encompasses the area from 0° to 2.5° longitude and from 87.5° to 90° latitude.

For each month there are three images and three data sets corresponding to reflected shortwave flux (RSW), outgoing longwave flux (OLR), and albedo respectively. The images are stored in GIF format while the data are stored in column ASCII format, suitable for reading with a spreadsheet. Each image displays the mean value for the respective parameter (shortwave, longwave, albedo) for the entire globe where the means are determined by first calculating the mean for each 2.5° latitudinal zone and then calculating the area weighted mean of the zone. The mean albedo is determined from the mean reflected shortwave and the incoming shortwave.

The regional data values that go into producing the images is a 72 by 144 matrix of 2.5° regions. This matrix represents 72 latitude zones, each zone containing 144 regions represented by longitude. There are thus 10368 2.5° grids that make an image. The first grid is centered at 88.75 N latitude, 1.25 longitude. The last grid is centered at 88.75 S latitude, 358.75 longitude. For more information on the ERBE instruments, availability of ERBE data sets, and analysis and research on ERBE data see references.

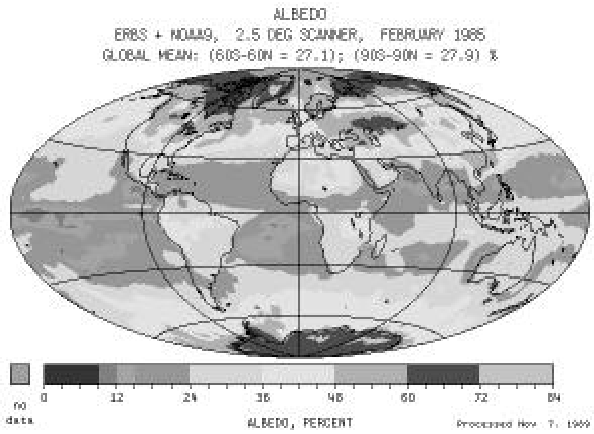
3. DATA AVAILABILITY

The 3-year data set will be available over a world-wide-web browser located at NASA, Langley Research Center, Hampton, VA 23681. Students will have access to the data in three ways. They can display GIF images of any month and visually observe changes from month-to-month or interannual variations. The data files for each month also have a spreadsheet format and can be downloaded into any spreadsheet application program for further analysis. Using a spreadsheet is a good way for students to get hands on experience with manipulating, subsetting, filtering, and plotting the data in an effort to find trends and anomalies. Students will also be able to interactively select monthly data that reside on the server and display images for particular times and regions for which they may be interested.

4. DISCUSSION OF DATA

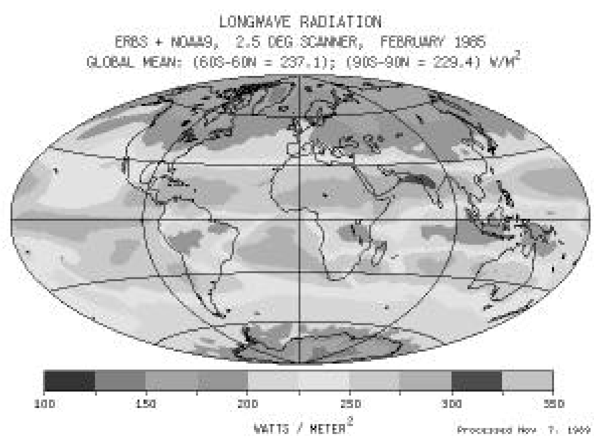
The data base on the server has monthly averaged albedos plus RSW an OLR and their associated GIF images for a 3-year time period. To give a flavor of what the students can observe and work with, three GIF images are given with a brief discussion of what they reveal. The images are for February 1995 and show global maps for each parameter. Each GIF image has a title and header that is very descriptive. The title gives which parameter is mapped. The header gives the satellite or combination of satellites from which the data was taken, the grid size in degrees, the type of instrument (scanner), and the year and month of the data. The header also gives a summary of the global mean value of the parameter for two ranges: from 60S - 60N latitude and from 90S - 90N latitude. The color bar at the bottom (gray scale in this paper) gives a scale for assigning values to regions of the respective parameters.

The first GIF image shows the albedo for February 1985.



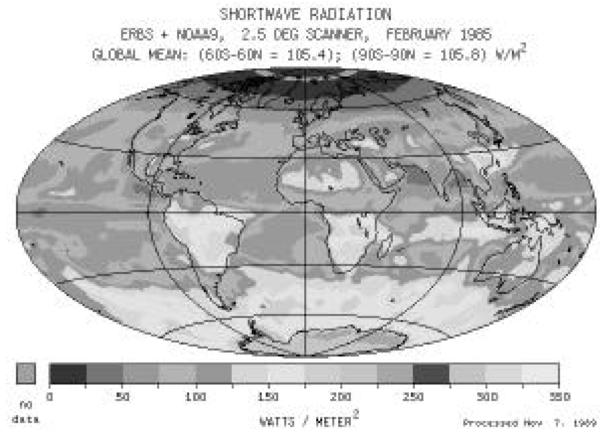
The grey scale image (although not as revealing as its color counterpart) shows that the equatorial and mid-latitude regions (± 30°) of the oceans have an albedo range from about 12% in some regions to 20 - 24% in most ocean regions. At higher latitudes albedo averages about 36% except for snow and ice regions (mostly polar regions) where the albedo may reach 70% due to high reflectivity.

The next GIF image shows the OLR for February 1985.



The OLR patterns are zonal in nature, and mainly influenced by surface temperature, cloud cover, cloud height, temperature lapse rate, and moisture content of the atmosphere. Three regions of low OLR (< 200W/M^2) occur between 0° S - 10° S over the Amazon Basin, Southern Africa, and Indonesia. Regions of high OLR are located in the tropical and subtropical regions within 30° of the equator where values can approach 300 W/M^2 in some regions, and are characterized by subsidence of dry air with few clouds. Polar regions have OLR that can approach values lower than 125 W/M^2.

The third GIF image shows the shortwave (RSW) for February 1985.



RSW is largest over the polar regions and oceans of the Southern Hemisphere where it ranges from 150 - 250 W/M^2 due to clouds and/or ice and snow. Most ocean regions in equatorial, tropical, subtropical, and mid-latitudes show RSW in a range from 50 - 100 W/M^2 due to cloud cover. Because it is winter, there is no RSW in the north polar regions, and the light ring at the North Pole means *no data available*. For most land areas in the Northern Hemisphere for February, RSW is about 100 - 125 W/M^2. For continental regions in the Southern Hemisphere, RSW is 100 - 200 W/M^2.

5. FUTURE PLANS

Plans are to expand the data set to include *Nimbus-7* WFOV data for those years which overlap ERBE data. That will allow students to directly compare radiation budgets for two different satellites. More years of data will be added to lengthen the time series, and a time series of surface radiation budget will be added. Tutorials with suggestions on what to do with the data will be added, and some data will be structured so that a scientific/graphic calculator can be used.

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